



RESEARCH DEPARTMENT

REPORT

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**SATELLITE BROADCASTING:  
protection ratio requirements for  
enhanced transmissions using Extended  
PAL vision and digital sound signals**

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## **SATELLITE BROADCASTING : PROTECTION RATIO REQUIREMENTS FOR ENHANCED TRANSMISSIONS USING EXTENDED PAL VISION AND DIGITAL SOUND SIGNALS**

**P. Shelswell, M.A., C.Eng., M.I.E.E.**

### **Summary**

*The BBC has conducted experiments with signals for satellite broadcasting to demonstrate the possibilities of enhancement to both vision and sound. The resultant signal has a different spectrum from that of a conventionally coded signal. Thus it is necessary to examine interference protection ratios for the enhanced signal and determine any differences from those assumed in the WARC satellite broadcast plan.*

*This report considers the interference effects of, and the protection ratios required by, an enhanced signal comprising an Extended PAL video signal and a digitally-modulated sound sub-carrier. It is shown that the protection ratios assumed in the WARC plan are not infringed.*

*At the time of the final preparation of this report Extended PAL was no longer being proposed as a UK DBS transmission standard. The report is, however, being issued as a complete record of the work.*

Issued under the authority of



Head of Research Department

**Research Department, Engineering Division,  
BRITISH BROADCASTING CORPORATION**

December, 1983

(RA-207)

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Section	Title	Page
	<b>Summary .....</b>	<b>Title Page</b>
<b>1.</b>	<b>Introduction .....</b>	<b>1</b>
<b>2.</b>	<b>Experimental work .....</b>	<b>1</b>
<b>3.</b>	<b>Results .....</b>	<b>3</b>
<b>4.</b>	<b>Conclusions .....</b>	<b>5</b>
<b>5.</b>	<b>References .....</b>	<b>6</b>

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# SATELLITE BROADCASTING : PROTECTION RATIO REQUIREMENTS FOR ENHANCED TRANSMISSIONS USING EXTENDED PAL VISION AND DIGITAL SOUND SIGNALS

P. Shelswell, M.A., C.Eng., M.I.E.E.

## 1. Introduction

The 1977 ITU World Administrative Radio Conference (WARC) on Satellite Broadcasting<sup>1</sup> based the planning of services on the use of a broadly-defined baseband signal. This was a video signal (which in the case of 625-line colour transmissions could be PAL or SECAM) with an associated f.m. sound carrier, both frequency modulated onto an r.f. carrier. Other modulating signals were not precluded providing that they would not cause greater interference than that caused by the reference system considered in the plan.

Before the UK Government<sup>2</sup> decided in favour of C-MAC, the BBC proposed that the video component should be basically a PAL signal. An option known as Extended PAL<sup>3</sup> was shown to give enhanced picture quality for new receivers, whilst giving satisfactory quality for existing PAL receivers. The sound would be transmitted using a digitally-modulated subcarrier<sup>4</sup>.

The present report considers the interference effects of a signal comprising Extended PAL video with a digitally-modulated sound subcarrier. Both digital sound and Extended PAL increase the high-frequency energy content of the baseband signal and thus modify the r.f. spectrum. The change in spectral distribution may affect the co-channel interference (c.c.i.) and adjacent channel interference (a.c.i.) protection ratios. The original specification of c.c.i. and a.c.i. is based on work by member countries of the EBU<sup>5,6,7</sup>. In particular, a templet was proposed defining the protection ratios required. This was later adopted as a basis for planning by WARC.

For a new signal specification to be acceptable it must not cause greater interference than the limits specified in the WARC plan. Although the plan only specified the effect of interference by new systems on the planned transmission standards, it is desirable that both the interference of the planned standard on any new standard and any new standard with itself should also lie within the templet.

This report describes experimental work carried out to determine the protection ratio requirements when one or more of the satellite broadcast transmissions uses Extended PAL and

digital sound signals.

## 2. Experimental work

In the experimental work an unwanted signal was added to a wanted transmission. The level and frequency of the unwanted signal could be controlled. The transmissions could be either the standard WARC signal (using PAL system I video) or Extended PAL with digital sound.

The main system parameters are given in table 1.

*Table 1. System Parameters\**

	WARC Channel	Enhanced Channel
Video signal	PAL System I	Extended PAL
Bandwidth	5.5 MHz	10 MHz
Pre-emphasis	CCIR Rec. 405-1	CCIR Rec. 405-1
Deviation	13.5 MHz pk-pk	13.5 MHz pk-pk
Energy dispersal	none	none
Sound signal	f.m.	QPSK
Modulation	none	pseudo random sequence (at 704 kbit/s)
Subcarrier frequency	6.0 MHz	7.0 MHz
Deviation of main carrier by sub-carrier	5.6 MHz pk-pk	2.5 MHz r.m.s.

Figure 1 shows a block diagram of the equipment used for the tests. These were performed using a 70 MHz carrier frequency for the wanted channel. The unwanted channel was obtained from a 70 MHz modulator using a double mixing

\*Wherever possible these comply with CCIR Rec. 600<sup>8</sup>.

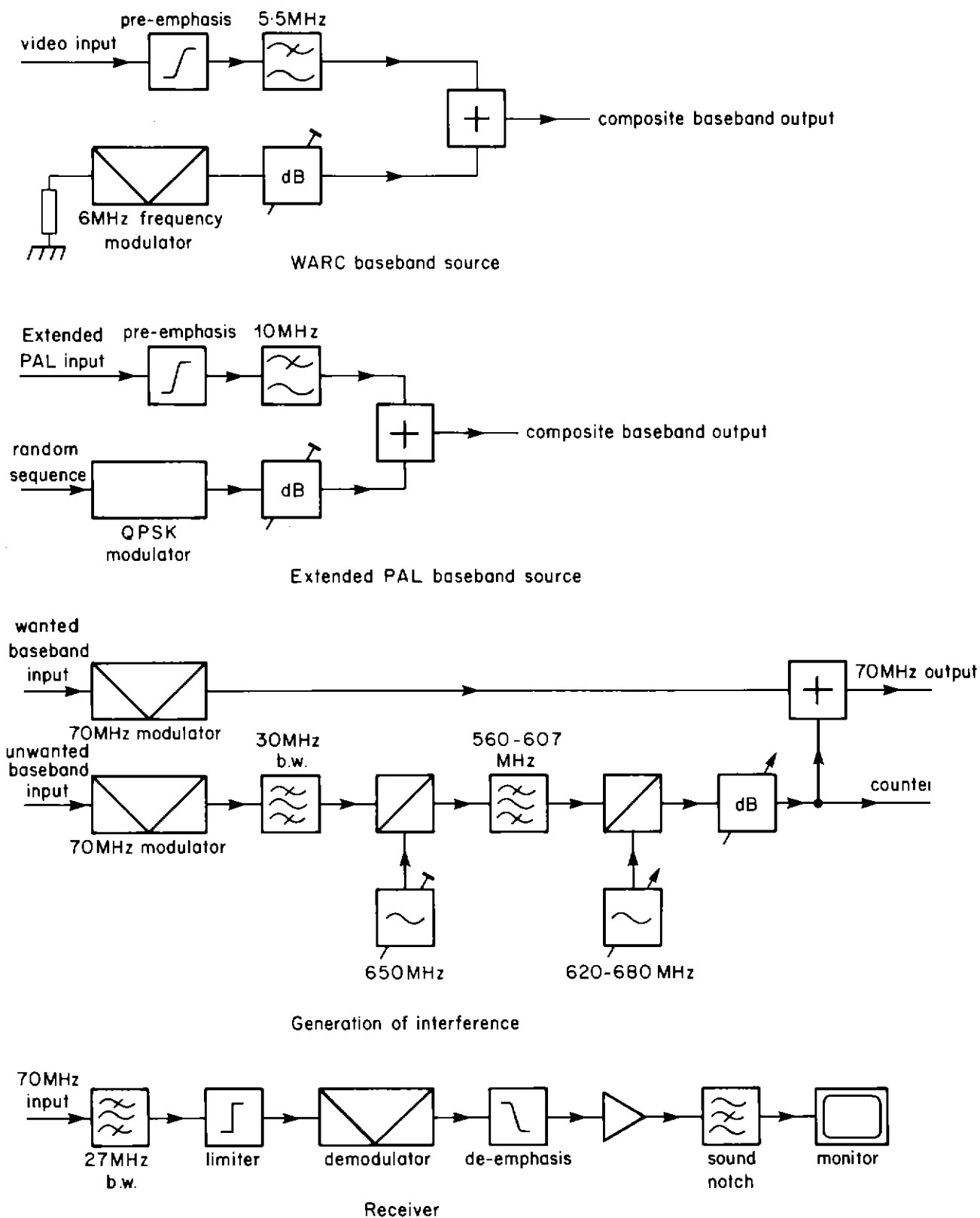


Fig. 1 – Experimental arrangement

process. The combined signal was then filtered using a four-pole Tchebycheff i.f. filter of 27 MHz bandwidth and demodulated conventionally. The resulting video signal was displayed on a high-quality picture monitor.

Four combinations of interference were tested. These are listed in Table 2.

Table 2. Test Conditions

Test Group	Wanted Channel/ Receiver	Unwanted Channel
1	WARC	WARC
2	WARC	Enhanced
3	Enhanced	WARC
4	Enhanced	Enhanced

In determining the protection ratio required, there are two possible methods which may be used. The first is to allow individual observers to control the level of impairment until it is judged to be just perceptible in the absence of other impairments. The second is to ask groups of observers to grade different levels of interference and then deduce the level which corresponds to the required subjective impairment (e.g. just perceptible impairment) from these results. Both methods were used.

In the experiments using the first technique two observers skilled in judging picture quality adjusted the level of unwanted signal for just perceptible interference. The impairments were noted in a darkened laboratory at a distance of only twice picture height. This is a very critical test and ensured that the impairment would always be less than half of one grade on the CCIR 5-point impairment scale\* under normal viewing conditions (i.e. viewing at six-times picture height).

\* The CCIR 5-point impairment scale is shown here:-

Grade	Impairment
5	Imperceptible
4	Perceptible but not annoying
3	Slightly annoying
2	Annoying
1	Very annoying

A further set of experiments was performed in which the latter more standard method was used. A viewing distance of four-times picture height was used in a series of subjective tests with 9 observers; although this is still a more critical viewing distance than that specified in CCIR Rec. 500<sup>9</sup> it is becoming a more common viewing distance. In the test, observers were asked to grade impairments (on the CCIR 5-point impairment scale) produced by randomly chosen levels of c.c.i. and a.c.i. The test sequence used a switched comparison between an unimpaired signal and an impaired signal. The monitor was set up before the tests so that peak white was about 65cd/m<sup>2</sup> and black level was adjusted using a test waveform (PLUGE).

The test pictures in the wanted channel were chosen to be those particularly sensitive to the impairments expected. (Experience has shown that dark grey or blue backgrounds are most sensitive to the patterning effects caused by c.c.i. and a.c.i.). The unwanted pictures were also chosen to be critical (i.e. giving relatively large amounts of high frequency luminance with Extended PAL signals). In the first series of tests Test Card F and 'Lion' (a lion and a vase of flowers on a blue background) were used as the wanted signal sources and 100% colour bars, EBU test slide 'Couple' and a zone plate\* were used as the unwanted signal sources. In the second series of tests 'Lion' was replaced by EBU slide 'Boats' in the wanted channel and zone plate was used in the unwanted channel.

### 3. Results

The results from the first series of tests are shown in Figs. 2 and 3 and Table 3 whilst those from the second series of tests are shown in Figs. 4 and 5.

The protection ratio required when a wanted channel is interfered with by an unwanted channel is dependent on the offset of the unwanted channel. Figure 2 shows a typical plot of protection ratios required when the wanted channel is a WARC channel and the unwanted is either a WARC or an enhanced channel. These are compared with the WARC assumed protection ratios<sup>1</sup> (dashed lines). In practice we are only concerned with unwanted interference at specific frequencies: co-channel and  $\pm 19.18$  MHz offset. Only these frequencies are considered further.

Table 3 gives the protection ratios required

\* 2-dimensional, full-amplitude, luminance frequency sweep.

difference in levels of wanted and unwanted carriers for just perceptible interference at twice picture height, dB

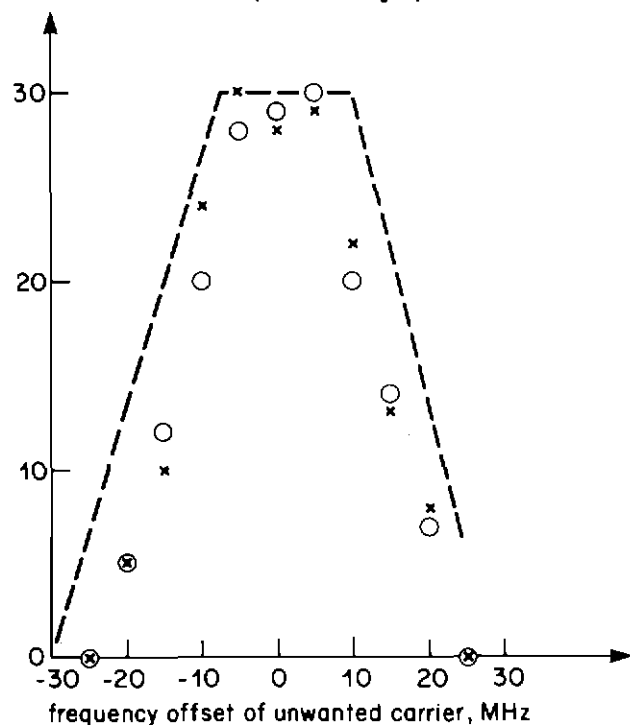


Fig. 2 — Measured protection ratios for test groups 1 and 2

difference in levels of wanted and unwanted carriers for just perceptible interference at twice picture height, dB

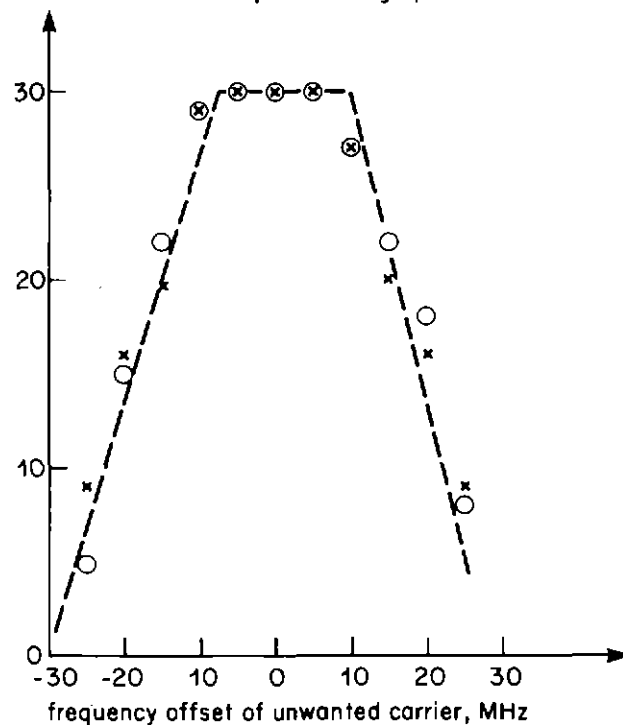


Fig. 3 — Measured protection ratios for test groups 1 and 2

wanted channel: WARC  
unwanted channels:  
WARC x  
Extended PAL o

Picture sources  
wanted channel: test card F  
unwanted channel: EBU  
slide 'couple'

in the different test conditions. Results for the two Extended PAL channels (Test Group 4) were obtained using the same picture sources for both wanted and unwanted channels, but with a timing offset (approximately  $5\mu\text{S}$ ) and this result should only be regarded as an indication and is not directly comparable with those for the other Test Groups. The second set of experiments used test conditions truly representative of Test Group 4 and the results of these tests (detailed below) should be regarded as definitive.

There is little systematic change when Extended PAL is introduced. The Extended PAL signal is not necessarily a more critical signal despite its high frequency information. In most cases the differences are little more than the experimental error which was approximately  $\pm 1\text{ dB}$ . It is interesting to note that not only Test Group 3 (WARC enhanced channel) but also Test Group 1 (WARC reference conditions) exceed

wanted channel: WARC  
unwanted channels:  
WARC x  
Extended PAL o

picture sources  
wanted channel: lion  
unwanted channel: colour  
bars

the c.c.i. limit by 2 dB when viewed at twice picture height and when using critical test pictures. Thus the visibility of interference above the reference levels is due to the highly critical test conditions rather than the change of transmission standard.

Furthermore, the absolute values of the required protection ratios in the region of the adjacent-channel frequency offsets will also be dependent upon the characteristics of the receiver filter used (in this case a single 4-pole Tchebycheff design with a  $-3\text{ dB}$  bandwidth of  $27\text{ MHz}$ ) to some extent. However, the small differences between the results for PAL and Extended PAL should not depend critically upon the choice of filter.

Since a digital sound carrier was present in the channel for these tests, it may be that some of the differences in protection ratio could be

attributed to the change in sound subcarrier. An Extended PAL signal with little high-frequency content is similar to a normal PAL signal and, with such a signal, any difference in protection ratio can be ascribed to the sound subcarrier. One such signal is colour bars. Figure 3 shows the results for colour bars in the unwanted channel. They are similar for both systems. Thus we may infer that the presence of a digital sound subcarrier causes little change in a.c.i. and c.c.i. protection ratios.

Figures 4 and 5 show the subjective impairment caused by different levels of c.c.i. and a.c.i. for Extended PAL reception and an Extended PAL interfering transmission. If Extended PAL is to be used for DBS, it is desirable that at the planned protection ratios there is little subjective impairment. The protection ratios assumed are 30 dB for c.c.i. and 14 dB for a.c.i. to include all sources of interference. At these levels the impairments noted are better than grade 4.5 even with critical material. As Extended PAL transmissions are very similar to normal

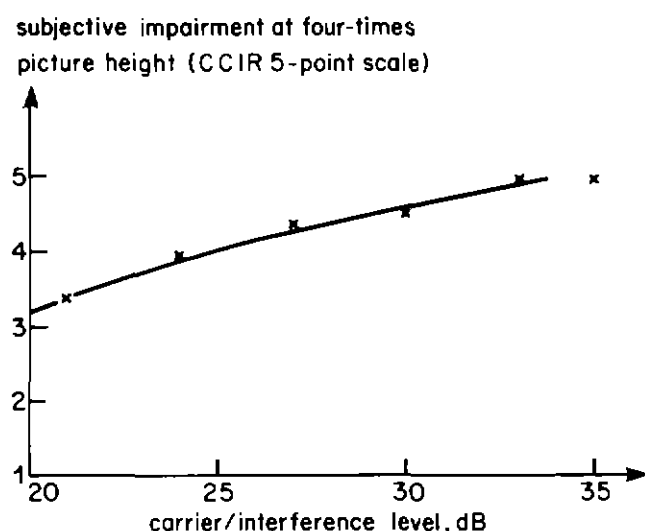


Fig. 4 — Subjective impairment of c.c.i. in Extended PAL systems

Table 3. Mean Carrier-to-interference ratio for just perceptible interference at twice picture height (dB)

Test Group (See Table 2)	Lower a.c.i.	c.c.i.	Upper a.c.i.
WARC Limits	14	30	14
1	11.4	32.0	12.5
2	10.6	30.0	13.0
3	13.2	32.0	11.5
4	7	28.3	11.7

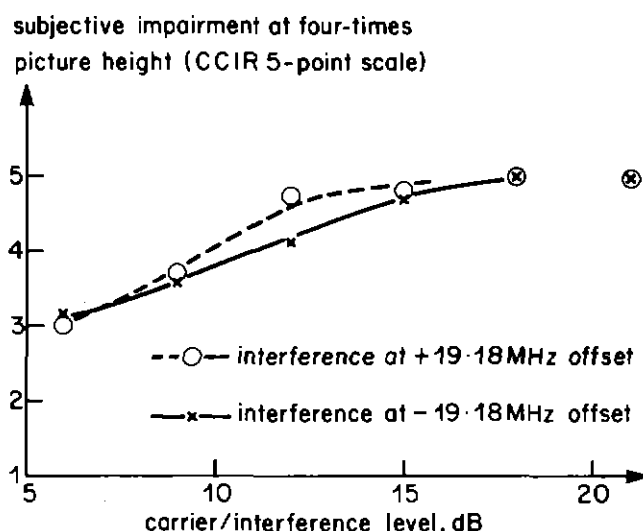


Fig. 5 — Subjective impairment of a.c.i. in Extended PAL systems

PAL transmissions for non-critical material, we may deduce that Extended PAL meets the WARC specifications under all signal conditions.

#### 4. Conclusions

The protection ratios required by a WARC channel for interference from a channel containing Extended PAL video signals and digital sound signals are about the same as those required for protection from a normal WARC channel with conventional PAL and analogue sound signals.

When an Extended PAL signal is transmitted the protection required against interfering WARC channels differs very little from that required between two interfering WARC channels.

When two Extended PAL signals interfere, there is an extra source of impairment only if there is significant energy in the high-frequency bands. This is a high-frequency incoherent signal which at the reference level for planning is, at worst, barely perceptible at four-times picture height. For most picture sources this impairment is not present but, at worst, the impairment levels are similar to those observed for conventional PAL signals assumed by the WARC specification.

The addition of a digital sound subcarrier makes no significant difference to the protection ratio requirements.

Thus the use of Extended PAL and digital sound signals for satellite broadcasting is completely compatible with the protection

requirements of the WARC Satellite Broadcasting Plan.

Although the experiments reported here are based on measurements with Extended PAL, the conclusions can be more general. Any transmission system with spectral requirements similar to those of Extended PAL is likely to comply with the WARC requirements. In particular this work demonstrated the possibility of increasing the bandwidth of MAC from the 6.0MHz originally proposed to the 8.4MHz in the current specification.<sup>10</sup>

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